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Distribution of *Alternaria* species among sections. 5. Species producing conidia with many longitudinal septa

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Abstract—Morphological examination of material conforming to the morphological descriptions of *Alternaria* species producing conidia with many longitudinal septa (but not phylogenetically characterized) allowed the inclusion of additional species in *Alternaria* sect. *Alternaria* (4 spp.; total spp. = 66), *A.* sect. *Cheiranthus* (1 sp.; total spp. = 3), *A.* sect. *Gypsophilae* (1 sp.; total spp. = 9), *A.* sect. *Infectoriae* (2 spp.; total spp. = 36), and *A.* sect. *Panax* (2 spp.; total spp. = 7). A complete list of species included in *Alternaria* sections *Cheiranthus*, *Gypsophilae*, and *Panax* is presented. Sixteen species were found to have intermediate morphology and could not be unambiguously assigned to any section.

Key words— *Alternaria asphodeli, Alternaria latifunda, Alternaria longispora, Alternaria prasonis*

Introduction

A recent series of large-scale works assessing morphology and molecular phylogeny of 13 generic alternarioid hyphomycetes has resulted in the elevation of 27 sections in the genus *Alternaria* (Lawrence & al. 2013, 2016; Woudenberg & al. 2013, 2014; Grum-Grzhimaylo & al. 2016). Many species of the enlarged genus have been assigned to these sections via morphological and/or molecular data. However, a number of *Alternaria* spp. have been described from herbarium specimens only and have no known living isolates. These species can be taxonomically considered using conserved morphological characters of the sporulation apparatus.

This work is a continuation of the series of articles dedicated to the morphological examination of *Alternaria* species that have not been assigned to any section using molecular data. Previous works assessed species with morphological features shared with existing members in *Alternaria* sect. *Porri* (Gannibal 2015), *A.* sect. *Alternaria* (Gannibal 2016), *A.* sect. *Infectoriae* and *A.* sect. *Pseudoalternaria* (Gannibal & Lawrence 2017), and *A.* sect. *Alternantherae* (species of which were previously considered to reside in the genus *Nimbya*) and *Nimbya* (Gannibal 2018). In this study we examined species that form elongated obclavate or ellipsoidal conidia with large numbers of longitudinal and oblique septa (1–2 or even 2–4 in most of the transverse segments).

Three sections, *Alternaria* sect. *Cheiranthus*, *A.* sect. *Gypsophilae*, and *A.* sect. *Panax*, are excellent candidates to serve as a "harbor" for species that produce elongated obclavate or ellipsoidal conidia with many longitudinal and oblique septa. Some species in sections *Alternaria* sect. *Alternaria*, *A.* sect. *Infectoriae*, and *A.* sect. *Porri* may also form elongated conidia with many longitudinal septa.

Alternaria sections *Cheiranthus*, *Gypsophilae*, and *Panax* are morphologically similar. All three sections possess species that form branched conidial chains of mostly 3–5 to 5–7 units. Mature conidia are of medium size (in most cases 50–150 × 15–25 µm), ellipsoidal or obclavate with several longitudinal and oblique septa in many or almost all transverse segments. Species that produce small conidia usually form fewer longitudinal septa (e.g., *Alternaria juxtiseptata*, *A. eryngii*). Lawrence & al. (2016) emended the description of *A.* sections *Cheiranthus*, *Gypsophilae*, and *Panax*. Furthermore, some minor morphological features should be mentioned. In combination with commonly used morphological characters these nonessential characters as well as ecological features can help to determine affiliation of a species with a section of *Alternaria*. For example: *A.* sect. *Panax* conidia more often form multiple lateral secondary conidiophores. *Alternaria* sect. *Gypsophilae* conidia have conspicuous constrictions near almost all septa; additionally, species in this section seem to have a strong plant host association (with four genera of *Caryophyllaceae*, tribe *Caryophylleae*) (Simmons 2002). It is challenging to define characteristic features for *A.* sect. *Cheiranthus* since it currently has only two morphologically rather divergent members.

Some species of other sections can resemble *A.* sections *Cheiranthus*, *Gypsophilae*, and *Panax* via several characters. A significant number of such species have been described from natural substrates: herbarium materials or plant parts placed in moist chamber. For example, conidia of several species in

A. sect. *Porri* (e.g., *A. cyamopsidis*, *A. euphorbiae*, *A. latispora*) have numerous longitudinal septa. Simmons (2007) has described some large-spored species from both herbarium specimens and living cultures. For each of *Alternaria solani* and *A. subcylindrica,* herbarium and culture conidia are similar. However, field conidia of *A. hibiscinficiens* were 1.5–2 times wider, did not form filiform beaks, and had more longitudinal septa (1–3 in most of transverse segments) in comparison with typical *A.* sect. *Porri* conidia produced in a moist chamber (Simmons 2007). Some other species in *A.* sect. *Porri* (e.g., *A. tagetica* and *A. sauropodis*) may produce conidia with several lateral secondary conidiophores, which is a general character for species in *A.* sect. *Panax*.

Species in *A.* sect. *Alternaria*, *A. tenuissima* and *A. citri*, can produce conidia with many longitudinal septa. Similar to *A. hibiscinficiens* in *A.* sect. *Porri*, *A. tenuissima* and *A. caudata* herbarium conidia are wider and have more intensive septation than conidia from culture on potato-carrot agar – PCA (Simmons 2007). Conidia of *A. citri* sampled from nature are also wider and have many more septa than conidia derived from colonies cultured on PCA medium. *Alternaria toxicogenica* under culture conditions has the largest conidia with the highest number of septa among *A.* sect. *Alternaria* members.

Alternaria triticina and *A. ventricosa* are examples of species in *A.* sect. *Infectoriae* with relatively large conidia with many longitudinal septa. *Alternaria triticimaculans* was studied by Simmons (2007) utilizing field specimens and cultured isolates (Simmons 2007). Conidia from herbarium samples were wider and had more intensive septation than those from culture as in the previous examples.

Simmons (2007) made some suggestions and linked some "strange" species with morphologically more well-described species or species-groups. Sometimes he combined a group of species that are now currently members of different phylogenetically validated sections. However, Simmons' viewpoint on species groupings differs somewhat as compared to the molecular phylogenetic studies and section descriptions that came much later (Lawrence & al. 2016).

The aim of this work was to assign *Alternaria* species that form elongated obclavate or ellipsoidal conidia with large numbers of longitudinal and oblique septa to sections using existing morphological descriptions.

Materials & methods

The morphology of all *Alternaria* species with legitimate names was analyzed with regard to conformity with criteria of *Alternaria* sections *Cheiranthus*, *Gypsophilae*, and *Panax*. The morphological assessment was based on protologue diagnoses and on illustrations published by Simmons (2007).

Results & discussion

Twenty-six species resembling *Alternaria* sections *Cheiranthus*, *Gypsophilae*, and *Panax* were found among unassembled *Alternaria* species. The evaluation of all possible sectional connections resulted in ten additional species being connected with known sections. Nine of these ten species have no known living isolates. Suggestions by Simmons (2007) on species similarity were not enough to link a species to any phylogenetically recognized group.

Only four additional species were recognized as belonging to *A.* sections *Cheiranthus*, *Gypsophilae*, or *Panax*. All *Alternaria* species in those three sections are listed in Table 1. Other species represent previously revised *A.* sections *Alternaria* and *Infectoriae* (Gannibal 2016; Gannibal & Lawrence 2017) or cannot be morphologically assigned to a section.

One additional species, *A. longispora*, was added to *A.* sect. *Gypsophilae*. *Alternaria longispora* was isolated from a host in *Caryophyllaceae*, as were all eight species previously assigned to *A.* sect. *Gypsophilae*. An additional species, *A. latifunda*, was added to *A.* sect. *Cheiranthus*, which previously comprised two morphologically divergent species.

Alternaria asphodeli and *A. prasonis* were added to *A.* sect. *Panax*, which previously comprised five species. *Alternaria prasonis* was supposed by Simmons (2007) to be a member of the infectoria species-group, where he also placed *A. avenicola* (*A.* sect. *Panax*). Only *A. prasonis* among species distributed among sections in this article has a living representative isolate (Simmons 2007).

Four species show high morphological affinity with *A.* sect. *Alternaria*. Three species have conidia similar to *A. tenuissima* field conidia (conical or subulate apex or short secondary conidiophores; obclavate shape) but somewhat larger: *A. calystegiae*, *A. diversispora*, and *A. guaranitica*. One species, *A. macalpinei*, produces conidia resembling *A. citri* field conidia (short oval or subsphaerical body) but somewhat larger. Including species previously listed (Gannibal 2016; 2018), currently 66 species fit the morphological parameters of *A.* sect. *Alternaria*.

Alternaria polytricha and *A. shaanxiensis* were added to *A.* sect. *Infectoriae*, despite Simmons' (2007) note that *A. shaanxiensis* is similar to *A. cheiranthi*, the type species of *A.* sect. *Cheiranthus*. Those species have conidial similarities with field specimens of *A. triticimaculans*. Roughly 50% of their conidia are obovoid (as in many *A.* sect. *Infectoriae* species) in contrast to the mostly obclavate conidia in *A.* sect. *Alternaria*. At the same time, many *A. polytricha* and *A. shaanxiensis* conidia are obclavate with apical secondary conidiophores or with a conical or awl-like apical cell (as in *A. tenuissima* field conidia; Simmons

TABLE 1. Section assignment of *Alternaria* species producing conidia with many longitudinal septa.

Alternaria* sect. *Cheiranthus
- *A. cheiranthi* (Lib.) P.C. Bolle (Lawrence & al. 2013, 2014; Woudenberg & al. 2013)
- *A. indefessa* (E.G. Simmons) Woudenb. & Crous (Lawrence & al. 2013, 2014; Woudenberg & al. 2013)
- *A. latifunda* E.G. Simmons

Alternaria* sect. *Gypsophilae
- *A. axiaeriisporifera* E.G. Simmons & C.F. Hill (Woudenberg & al. 2013)
- *A. ellipsoidea* E.G. Simmons (Woudenberg & al. 2013)
- *A. gypsophilae* Neerg. (Lawrence & al. 2013; Woudenberg & al. 2013)
- *A. juxtiseptata* E.G. Simmons (Woudenberg & al. 2013)
- *A. longispora* McAlpine
- *A. nobilis* (Vize) E.G. Simmons (Hoog & Horré 2002; Lawrence & al. 2013; Woudenberg & al. 2013)
- *A. saponariae* (Peck) Neerg. (Woudenberg & al. 2013)
- *A. vaccariae* (Săvul. & Sandu) E.G. Simmons & S.T. Koike (Lawrence & al. 2013; Woudenberg & al. 2013)
- *A. vaccariicola* E.G. Simmons (Lawrence & al. 2013; Woudenberg & al. 2013)

Alternaria* sect. *Panax
- *A. asphodeli* O. Săvul.
- *A. avenicola* E.G. Simmons, Kosiak & Kwaśna (Woudenberg & al. 2013)
- *A. calycipyricola* R.G. Roberts (Lawrence & al. 2013)
- *A. eryngii* (Pers.) S. Hughes & E.G. Simmons (Lawrence & al. 2013, 2014)
- *A. panax* Whetzel (Hoog & Horré 2002; Lawrence & al. 2013, 2014; Woudenberg & al. 2013)
- *A. photistica* E.G. Simmons (Hoog & Horré 2002; Woudenberg & al. 2013)
- *A. prasonis* E.G. Simmons

Additions to *Alternaria* sect. *Alternaria**
- *A. calystegiae* Nelen
- *A. diversispora* (Thüm.) E.G. Simmons
- *A. guaranitica* (Speg.) E.G. Simmons
- *A. macalpinei* E.G. Simmons

Additions to *Alternaria* sect. *Infectoriae***
- *A. polytricha* (Cooke) E.G. Simmons
- *A. shaanxiensis* T.Y. Zhang & J.Z. Zhang

Incertae sedis
- *A. bannaensis* W.Q. Chen & T.Y. Zhang
- *A. capsici-annui* Săvul. & Sandu
- *A. ellisii* Pandotra & Ganguly
- *A. hibiscina* (Thüm.) E.G. Simmons
- *A. interna* (McAlpine) P. Joly
- *A. iridicola* (Ellis & Everh.) J.A. Elliott
- *A. limnanthemicola* R.L. Mathur, Agnihotri & Tyagi
- *A. malvacearum* E.G. Simmons
- *A. mycophila* (Bubák & Dearn.) P. Joly
- *A. nerii* (Cooke) E.G. Simmons
- *A. ornatissima* (Ellis & Barthol.) P. Joly
- *A. papaveris* (Bres.) M.B. Ellis
- *A. peponicola* (Rabenh.) E.G. Simmons
- *A. putrefaciens* (Fuckel) E.G. Simmons
- *A. triticicola* V.G. Rao
- *A. ulmi* (Fuckel) E.G. Simmons

Names with bracketed annotations = species supported by phylogenetic data (in the cited references).
Unannotated names = species assigned to any section of *Alternaria* for the first time.
* For main species list see Gannibal (2016).
** For main species list see Gannibal & Lawrence (2017).

2007). The addition of those two species to *A.* sect. *Infectoriae* (Gannibal & Lawrence 2017) enlarged the section to 36 distinct morphological species.

Morphological data on the remaining 16 species known only from herbarium specimens are not sufficient to affiliate them to a particular section. Future molecular research on the remaining herbarium material offers hope for clarifying their taxonomic position. At this moment we consider species listed below as incertae sedis within the genus *Alternaria*.

Species sharing intermediate characters of *Alternaria* sections *Alternaria*, *Infectoriae*, and *Panax* are: *A. capsici-annui*, *A. ellisii*, *A. hibiscina*, *A. interna*, *A. limnanthemicola*, *A. malvacearum*, *A. mycophila*, *A. nerii*, *A. ornatissima*, *A. papaveris*, *A. peponicola*, *A. putrefaciens*, and *A. ulmi*. Simmons (2007) noted the similarity of *A. capsici-annui* with *A. triticicola* and *A. putrefaciens*, which are also incertae sedis. Simmons noted an absence of living *A. capsici-annui* isolates that can be used as references. A non-representative isolate of '*A. capsici-annui*' (CBS 504.74) clustered within species in *A.* sect. *Ulocladium* (Woudenberg & al. 2013). This species has relatively short conidia with no lateral secondary conidiophores and commonly with a moderate number of longitudinal septa. Thus, *A. capsici-annui* should likely be affiliated with *A.* sect. *Alternaria* or *A.* sect. *Infectoriae*. An assignment of a neotype of *A. capsici-annui* would give an opportunity to test this hypothesis.

Three additional species (*A. bannaensis*, *A. iridicola*, *A. triticicola*) share characters intermediate between *A.* sect. *Panax* and *A.* sect. *Porri* and are not clearly differentiated with regard to section affiliation.

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